IS 8161-1 (1999): Guide for Equipment Reliability Testing, Part 1: Principles and Procedures [LITD 2: Reliability of Electronic and Electrical Components and Equipment]

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भाग 1 सिद्धान्त एवम् क्रियाविधि

(पहला पुनरीक्षण)

Indian Standard

GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 1 PRINCIPLES AND PROCEDURES

(First Revision)

ICS 21.020, 31.020

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Price Group 8

FOREWORD

This Indian Standard (Part 1) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Reliability of Electronic and Electrical Components and Equipment Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

This Indian Standard was first issued in 1976. This revision has been undertaken to bring it in line with the latest philosophy and concepts in the field of reliability.

This standard which deals with the general principles and procedures is first in the series of Indian Standards for equipment reliability testing. To be able to write a detailed reliability test specification and perform a reliability test, the test engineer will need additional information which are dealt with in detail in other standards in this series and Annex A is intended to give brief diagrammatic guidance to the test specification writer and the test engineer on how to use IS 8161 series in preparing for, executing and interpreting equipment reliability tests.

This standard is largely based on IEC Pub 605-1(1978) 'Equipment reliability testings: Part 1 — General requirements' issued by the International Electrotechnical Commission (IEC).

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it should be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

GUIDE FOR EQUIPMENT RELIABILITY TESTING

PART 1 PRINCIPLES AND PROCEDURES

(First Revision)

1 SCOPE

This standard (Part 1) deals with general principles and procedures for equipment reliability testing.

2 REFERENCES

The Indian Standards listed in Annex B are necessary adjuncts to this standard.

3 TERMINOLOGY

For the purpose of this standard, the terms and definitions covered in IS 1885 (Part 39) shall apply in addition to the following.

3.1 Reliability Compliance Test

An experiment used to show whether or not the value of a reliability characteristics complies with the stated reliability requirements.

3.2 Reliability Determination Test

An experiment used to determine the value of a reliability characteristic.

NOTE — Analysis of existing data may also be used for reliability determination.

3.3 Laboratory Reliability Test

A reliability compliance or determination test made under prescribed, controlled and simulated test conditions, related to field conditions.

3.4 Field Reliability Test

A reliability compliance or determination test made under recorded conditions of use in the field.

3.5 Producer's Risk

The probability of rejection, if the equipment has the acceptance value of the specified reliability characteristics.

3.6 Consumer's Risk

The probability of acceptance if the equipment has the unacceptable value of the specified reliability characteristics.

3.7 Recurrent Failures

Two or more failures occurring either:

a) in the same location, or

b) in the same part in differnt locations but similar application, or

c) in parts of identical type and manufacture, or

d) in the same point of the test cycle but not simultaneously.

4 INTRODUCTION

4.1 This standard provides general principles as well as specific recommendations on procedures for equipment reliability compliance and determination testing. The principles set forth are suitable for all types of equipment, such as electronic, electromechanical and mechanical. The term equipment is used here as being synonymous with equipment and/or system.

4.1.1 The compliance test is normally used as a condition of acceptance of the equipment by the customer. The determination test is normally used to provide information where a specific reliability requirement has not been stated.

4.2 The tests provided in this standard are not intended to replace ordinary tests, such as type tests, functional performance tests, environmental tests and component tests.

4.3 It should be noted that equipment reliability testing is only one of the possible elements of a reliability programme with the objective of increasing the reliability assurance in design,development and production of new equipment. This standard, however, does not include guidance for selecting the appropriate elements of a complete reliability programme for a particular case and elements of such a programme. General guidelines on the principles of a reliability programme are covered in IS 7354 (Part 1) and IS 7354 (Part 2).

4.4 The inclusion of reliability testing in a general equipment specification depends upon many factors. Among the most improtant of these are:

a) applicable product history,

b) the consequences of inferior equipment reliability with respect to safety and economy,

c) the cost of reliability testing,

d) the time required for reliability testing,

e) the possibility of obtaining reliability assurance by activities other than reliability testing, and

f) the availability of representative samples.

4.5 The final conclusions drawn from a reliability compliance test should not be based solely upon the formal accept/reject decision reached. The causes and consequences of each failure observed during a reliability test should be analyzed in detail and any possibility of taking effective corrective actions should be investigated.

4.6 A reliability growth (or improvement) programme employs reliability testing, but with the principal object of upgrading the reliability. This takes place by successive analysis of failures and corrective modifications to the equipment under test. This process may, therefore, be an essential preliminary to compliance or determination testing whenever there is a reason to believe that the equipment reliability is inadequate.

4.7 Great care should be taken if the results of a reliability compliance or determination test are extrapolated to:

a) other equipment populations,

b) enviromental conditions differing from the test conditions, or

c) longer time of operation than used during the testing.

Also, due to the complexity and variability of usage environments for most equipment applications, strict correlation between the reliability figures obtained from laboratory reliability testing and those experienced in actual should not be expected in each individual case.

4.8 A flow chart giving an overall description of preparations for and execution of reliability compliance tests is presented in IS 8161 (Part 11).

5 OBJECT

The object of this standard is to provide recommended methods and procedures for the purpose of equipment reliability testing. These include how to:

a) specify reliability requirements for compliance testing,

b) select test conditions for reliability test,

c) prepare detailed reliability test specifications,

d) perform laboratory and field reliability tests,

e) evaluate information from reliability testing, and

f) write reliability test reports.

6 APPLICABILITY OF THE METHODS

6.1 The details given in this standard are intended to be applied:

a) when it is considered desirable in a general equipment specification to incorporate reliability requirements to be verified by reliability compliance testing. This standard is thus intended to be used by the various Committees dealing with equipment standardization; and

b) when an equipment manufacturer, test agency or user intends to ascertain reliability information based on reliability determination testing for the particular type or application of the equipment.

6.2 Reliability compliance tests as applied for **6.1** (a), should always be planned beforehand. Existing test data are, therefore, not considered suitable for this purpose. For reliability determination as applied to **6.1** (b), appropriate particular tests are normally performed. However, the use of existing data may be acceptable, provided that the data are sufficiently complete and correct.

6.3 Although primarily intended for electronic or electrical equipment, the methods are also applicable to other types of equipment and systems containing electromechanical and mechanical, including pneumatic and hydraulic devices. The equipment may be repaired or unrepaired in use during the testing. The methods are also applicable to limited-life devices.

6.4 The methods may be applied in any one or more of the following product phases : development (prototype), preproduction, normal production and field use. The tests may be included in an initial qualification procedure, in a requalification procedure, and in an acceptance procedure during normal production. They are applicable for laboratory tests as well as for field tests.

6.5 The methods are applicable when reliability is expressed in terms of the following reliability characteristics:

a) failure rate, mean time between failures, mean time to first failure or other parameters of the distribution of times to or between failures; and

b) success ratio for a given time interval or number of operations (trials).

6.6 The applicability is not restricted to any particular distribution of times to failure. Wherever 'time' is used in this standard, this variable may be replaced by distance, cycles or other quantities or units as may be appropriate. In case of conflict between this standard

and the relevant equipment specification(s), the latter shall apply.

7 PRINCIPLES OF RELIABILITY COMPLIANCE TESTING

7.1 Reliability Requirements

Operational reliability requirements for a particular equipment should be derived from total system considerations and expressed in usage-oriented terms. The requirements should refer to the whole range of conditions of use that is, operating, environmental and maintenance conditions, and the total period of time for which satisfactory performance is required. Reliability requirements for compliance testing should be specified in test-oriented terms and be designed to reach good correspondence between the value of the reliability characteristic resulting from testing and the value of the operational reliability under use conditions. It shall be realised, however, that close correspondence between test and use reliability is difficult to achieve. The usage-oriented operational reliability requirement should always be converted into suitable requirements for reliability compliance testing wherever reliability requirements are to be verified by testing.

7.2 Requirements for Reliability Compliance Testing

Any requirement for reliability compliance testing of an equipment should be included in or enforced by the equipment specification. They should be complete enough to define all particular details of the reliability compliance test. When reliability compliance testing is specified in accordance with this standard. Information is required on the items listed in **7.2.1** to **7.2.5**, if applicable.

7.2.1 *Test Items and Type of Test*

a) Identification of the (type of) equipment to be tested,

b) Type of test to be performed: laboratory or field test (*see* **7.3**), and

c) Population of the equipment from which the test sample shall be drawn and any special procedure of test item selection (*see* **9.2**).

7.2.2 *Reliability Characteristic and Compliance Test Plans*

a) Applicable for reliability characteristic and statement of the acceptance value. When the reliability characteristic refers to a system and is to be derived from separately verified reliability characteristics for individual sub-units, the derivation procedure to be applied shall also be specified and shall include the applicable reliability block diagram, and

b) The compliance test plan to be used. The plan used should preferably be chosen from the applicable parts of this standard (*see* **9**).

7.2.3 *Test Conditions and Test Cycle*

a) Operating and environmental test conditions including load and supply conditions and actual manipulation (*see* **10.2** and **13**);

b) Preventive maintenance to be applied during the test (*see* **10.3** and **13**); and

c) Test cycle for the sequence and combinations of **7.2.3(a)** and **7.2.3(b)** (*see* **10.1**).

7.2.4 *Test Item Performance and Failure*

a) Functional parameters to be monitored during the test and criteria for test item failures (*see* **11.1** and **11.2**);

b) Types of failures demanding immediate reject decision (*see* **11.4.1**);

c) Types of failures to be considered as non-relevant test item failure (*see* **11.3**);

d) Periods of test time to be considered as relevant test time (*see* **11.5**); and

e) Minimum and/or maximum relevant test time or number of operations; for each test item (*see* **11.5**).

7.2.5 *Pre-test Conditions and Corrective Maintenance*

a) Tests, adjustments, calibrations and operation time (burn-in) of the test items prior to the reliability test (*see* **9.1** and **12.1**); and

b) Corrective maintenance procedures to be applied, including any permitted replacement of failed parts or items (*see* **12.2**).

7.3 Reliability Compliance Test Methods

7.3.1 Prior to the start of an equipment reliability test, a detailed reliability test specification should be prepared. This should contain:

a) requirements for reliability compliance testing according to **7.2**, detailed for the particular equipment to be tested;

b) derived requirements or a list of the test facilities to be used, including environmental facilities, monitoring equipment, maintenance facilities and test programme control;

c) instructions for running the test and actions to be taken when failures occur in test items and test facilities; and

d) instructions for reporting and actions to be taken due to test decisions.

7.3.2 A check-list of items to be included in the

detailed reliability test specification or the equipment specification is given in **15**.

7.3.3 Equipment reliability testing may be accomplished by either laboratory or field testing.

7.3.4 Laboratory tests have the advantage that the test conditions may be exactly defined and controlled giving reproducible and comparable results. In addition, the monitoring of the test item performance and failure indications are under better control. Laboratory test conditions in many cases may be designed to take better account of limiting conditions of application. Earlier test decisions and problem identification are possible, permitting more timely corrective actions.

7.3.5 Field tests may be performed in some cases since they provide more realistic test results and require fewer test facilities. The direct cost of a field test may often be lower than that of a corresponding laboratory test. The test item may be used in normal operation. The inability to perform field tests under closely controlled conditions may, however, represent a significant disadvantage. The reporducibility of a field test is generally lower than that of a laboratory test.

7.3.6 Laboratory and field test methods are very similar with respect to the requirements and performance of the reliability testing. Special considerations for field reliability testing are specified in **13**.

8 PRINCIPLES OF RELIABILITY DETERMINATION TESTING

8.1 In reliability determination testing, estimates of the reliability characteristics of interest are obtained from analysis of test observations. The applicable reliability characteristics shall be stated.

8.2 The requirements for test conditions, test item performance, test observations and test procedures are the same for reliability determination testing as for reliability compliance testing. The list of requirements as given in **7.2.1**, **7.2.3**, **7.2.4** and **7.2.5**, therefore, apply. As there is no predetermined quantitative reliability requirement in case of determination testing, **7.2.2** does not apply.

8.3 A detailed reliability test specification should be prepared and laboratory or field tests may be applied as for compliance tests (*see* **7.3**).

8.4 The statisitical methods for reliability determination testing are described in **9.5**. Existing data from earlier tests or field observations may be acceptable for reliability determination, provided the data are sufficiently complete, well-established and applicable to the situation.

9 TEST ITEM SAMPLING AND STATISTICAL TEST PLANS

9.1 General

The test planning for reliability testing is necessarily based on statistical considerations because the reliability characteristics are statistical in nature.

9.1.1 In case of mean time between failures (mean), failure rate or other distribution parameters being required, the testing is performed as a time test during which the relevant times to failure are observed. An assumption of the distribution of times to failure shall be made.

9.1.2 In case of success ratio being required, the testing implies that only the number of trials and failures or the total number of items and number of failed items are to be counted and treated statistically.

9.2 Population and Test Item Sampling

9.2.1 The equipment reliability testing may be applied to any of the following:

a) Development models or prototypes;
b) Pre-production lot; and
c) Production lot or lots.

9.2.2 The number of items in the population may in some cases be a single item. The population shall be essentially homogeneous, that is, the items are produced by the same methods and under similar circumstances in order to allow representativeness of the reliability test.

9.2.3 Items to be tested should be randomly selected from the relevant population. The relevant population and any special procedure of test item selection shall be stated in the detailed reliability test specification. When applicable, the customer or independent test agency should make this selection.

Any burn-in or other prior exposure to stress (for example, handling or transportation) of the test samples shall be equal to that of the deliverable equipments.

9.3 Underlying Distributions

The random variables relevant to a reliability test will be either of the following:

a) A continuous random variable: time to failures or time between failures with an underlying continuous distribution of the exponential type, Weibull or normal type.
b) A discrete random variable: the number of failures or failed items with a discrete distribution of the binomial type.

NOTE — Other distributions may also be applied, if their applicability is substantiated.

9.3.1 *Guidance for Selection of Assumed Distribution*

9.3.1.1 *Continuous distributions*

If the random variable is time to failure or time between failures, the following distributions should be considered:

a) *Exponential* — For use when the failure rate has a constant value. A constant failure rate period exists for many equipments after an early failure period (decreasing failure rate) and before a wearout failure period (increasing failure rate). Approximately constant failure rate may also be exhibited after stabilization by equipment subjected to a series of replacements of parts due to preventive or corrective maintenance, even if the parts separately have an increasing failure rate.

b) *Normal* — For use when the times to failure approximate to a Gaussian distribution and exhibit an increasing failure rate indicative of wearout failure mechanisms. Although this distribution may be approximated by a Weibull distribution with the proper selection of parameters, the normal distribution may advantageously be used because of a number of statistical methods being available based on the assumption of normality.

c) *Weibull* — For use with decreasing or increasing failure rate. Complex equipments may show decreasing failure rate while equipments with wearout mechanisms and those containing a high proportion of non-repaired redundant elements normally exhibit increasing failure rate. The Weibull model is generally successful for a wide number of applications. However, statistical procedures are not as extensively available as the exponential and normal distributions.

9.3.1.2 *Discrete distributions relevant to success ratio*

When all test items or trials are to be classififed as either failed or non-failed, the success ratio is used as reliability characteristic. Applicable statistical distributions include the Binomial, Poisson and Hypergeometric distributions.

For the test plans given in IS 8161(Part 5), use the Binomial distribution in the determination of sample sizes and operating characteristic curves.

NOTES

1 Binomial distribution is to be used if the population can be considered to be infinite as in the case for repaired equipment. It is also useful as an approximation of the Hypergeometric distribution if the population is at least 10 times the sample size.

2 Poisson distribution is to be used as an approximation to the binomial distribution if the success ratio is greater than 0.90 and the population is more than 10 times the sample size.

9.3.2 *Initial Assumption of Distribution of Times to Failure or Times Between Failures*

9.3.2.1 For equipment, the initial assumption shall be a constant failure rate described by the exponential distribution, unless a documented analysis or engineering judgement justifies the selection of any other distribution (*see* **9.3.1**).

9.3.2.2 The basis for the assumption of any other distribution should be reliability investigations or analysis made prior to the reliability test. This evaluation may be made during the design and development of the equipment or a posterior for an equipment which has been built with or without any reliability requirement. The detailed reliability test specification shall state the assumed distribution, if other than exponential.

9.3.3 When called for by the detailed reliability test specification, tests for the validity of the initial distribution assumption shall be performed using the methods described in IS 8161 (Part 6/Sec 1 and 2). The validity tests may be based on the same data as the reliability test.

9.4 Reliability Compliance Test

The purpose of **9.4.1** to **9.4.4** is to describe the statistical test plans used for equipment acceptance or rejection to a specified reliability value. This requires that all rules regarding aceptance and rejection are established before the test starts. The detailed reliability test specification shall, therefore, state the test plan to be used.

9.4.1 *Tests Appropriate to Failure Rate and Mean Time Between Failures Assuming Constant Failure Rate*

For constant failure rate described by the exponential distribution, a test plan from IS 8161(Part 7) should be chosen. These are of the following two basic types which may be performed with or without replacement:

a) *Truncated sequential test* — During the conduct of the test, the test items are monitored continuously or at short intervals, and the accumulated relevant test time and the number of relevant failures are compared with the established criteria for determining whether to accept, reject or continue testing.

b) *Time/failure terminated tests* — During the conduct of the test, the test items are monitored continuously or at short intervals, and the relevant test time is accumulated until either a predetermined amount of relevant test

time has been exceeded (accept), or a predetermined number of relevant failures has occurred (reject).

9.4.1.1 *Guidance for choice of type of test plan*

Each of the two basic types of test plans have number of economic and administrative advantages as described below:

a) Truncated sequential tests:
   1) Advantages
      i) The average number of failures to a decision is a minimum.
      ii) The average accumulated test time to a decision is a minimum.
      iii) The test has fixed maxima with respect to accumulated test time and number of failures.
   2) Disadvantages
      i) The number of failures and, therefore, the test item costs, will vary in a broader range than for a similar time/failure terminated test. The consequences are the creation of administrative problems in the scheduling of test items, test equipment and manpower.
      ii) Maximum accumulated test time and number of failures could exceed those for the equivalent time/failure terminated test.

b) Time/failure terminated tests:
   1) Advantages
      i) Maximum accumulated test fixed. Therefore, maximum requirements for test equipments for test equipment and manpower are fixed before testing begins.
      ii) Maximum number of failures is fixed prior to testing. Therefore, the maximum number of test items may be determined in case of testing without repair or replacement.
      iii) Maximum accumulated test time is shorter than for a similar truncated sequential test.
   2) Disadvantages
      i) On the average the number of failures and the accumulated test time will exceed those of a similar truncated sequential test.
      ii) Very good equipment or very bad equipment needs to experience the maximum accumulated test time or number of failures to make a decision which may be made sooner with a similar truncated sequential test.

9.4.2 *Tests Appropriate to Non-constant Failure Rate*

Applicable for equipment with an increasing or decreasing failure rate.

9.4.3 *Tests Appropriate to Success Ratio*

9.4.3.1 When the reliability characteristic is success ratio, the planning of the test may be based on either of the following:

a) Fixed number of trials, or
b) Fixed number of successes, or
c) Fixed number of failures.

9.4.3.2 Reliability compliance tests for the success ratio are described in IS 8161 (Part 5).

9.4.4 *Risks Associated with Testing*

Incorrect decisions may be made for a number of reasons. The major ones include manner of selecting the test items, selection of the distribution assumption, and the statistical decision risks — consumer's and producer's risk.

9.4.4.1 *Risks associated with the selection of test items*

The choice of population from which the test items are sampled is usually made on the basis of schedules, technical conditions and economy. The risks connected to this choice may normally not be evaluated numerically.

In practice, reliability compliance tests are often performed with development or pre-production models in order to reach a decision early in the production cycle. Often development and pre-production models are not representative of the production lots, which due to learning and reliability growth may result in an unwarranted reject decision.

The sample of test items should be as representative of the chosen population as possible in order to provide information for judgement about the population. This may be ensured only by the procedure of selecting the test items at random. The risks of the population not being homogeneous and any part of the population being over-represented cannot be numerically determined.

9.4.4.2 *Risks due to selection of distribution assumption*

The initial assumption of a constant failure rate is recommended in **9.3.2**. Recognizing that this assumption may not hold for all equipments, it is necessary to examine the consequences of the assumption of a constant failure rate to equipments that actually have decreasing or increasing failure rate.

In general, if the actual test time on each equipment is less than the true equipment mean time between

failures, equipment that exhibits a decreasing failure rate will have a lower probability of passing the test than equipment that exhibits a constant failure rate. Similarly, equipment with an increasing failure rate will have a higher probability of passing a reliability compliance test based on constant failure rate. The latter case may lead to acceptance of equipment with unacceptable long-term reliability levels.

9.4.4.3 *Decision risks*

To minimize the probability of rejection of an equipment, it is necessary for the producer to ensure that the equipment has a better value of the reliability characteristic than the specified acceptable value.

The decision risks are shown clearly by the operating characteristic curve of the test plan. The producer and user may agree on the decision risks to be selected for a given test, balancing these risks against the cost of additional testing required to reduce them, and other factors, such as equipments, facilities and time available.

Operating characteristic curves are given for all compliance test plans included in the other parts of this standard.

If separate compliance tests are performed on individual sub-units of equipment, the risks to make a wrong accept or reject decision for the complete equipment are higher than for a single test on the complete equipment.

9.5 Reliability Determination Tests

When no quantitative reliability requirement is specified, reliability tests may be made to assess the reliability achieved by an equipment. The procedure is to statistically analyse the obtained data in order to estimate the reliability characteristic in question and, if desired, to determine a confidence interval around this point estimate. The confidence interval includes the unknown true value of the characteristic with a certain probability, the confidence level.

9.5.1 *Methods of Estimating Reliability Characteristics*

Reliability determination tests which are based on time as the variable, assuming a constant failure rate described by the exponential distribution, may either be terminated after a fixed amount of relevant test time has elapsed or after a fixed number of relevant failures have occurred. Tests with or without repair or replacement of failed items may be used to obtain point estimates and confidence limits of failure rate and mean time to/between failures.

If a Weibull or Normal distribution may be assumed, the observations are treated by graphical and, in some cases, numerical methods to determine point estimates of the distribution parameters. Confidence limits are given only for the Normal distribution.

Point estimates and confidence intervals for the success ratio are obtained from tests based on a number of trials or items. Each trial or item is either considered to be a success or a failure. The treatment of observations in this case is based on the Binomial distribution or, for a large number of failures, on the Normal distribution.

Recommended methods for determining the point estimates and confidence intervals mentioned above are given in IS 8161 (Part 4).

9.5.2 *Accumulated Testing*

If a reliability determination test consists of placing a number of items on test with no definite pre-determined termination procedure, the reliability may be evaluated at any time based on the accumulated test time and failures.

For constant failure rate described by the exponential distribution , it is not necessary that all units be placed on test at the same time or be tested for the same time period. The results of all tests for all time periods are collected and point estimate and confidence intervals are calculated from the accumulated results. The confidence limits should be obtained using the same procedure as for a test terminated after a fixed amount of test time noted in **9.5.1**.

For success ratio it is always possible to calculate point estimate and confidence limits from the accomulated test results.

9.5.3 *Risks Associated with Testing*

Errors associated with point estimates and confidence intervals are introduced in a similar manner as the risks discussed in **9.4.4.1** and **9.4.4.2** that are associated with compliance testing.

10 TEST CONDITIONS

Test conditions as used in this standard refer to any factor or action, apart from the inherent properties of the test items themselves, which might affect the occurrence of test item failures. The test conditions include operating conditions, environmental conditions and preventive maintenance. Corrective maintenance during the testing is described in **12**. Test conditions for field testing are discussed in **13**.

10.1 General Considerations for the Choice of Test Conditions

10.1.1 The following major factors should be taken into consideration while selecting equipment reliability test conditions:

a) Basic reason for requiring or performing a reliability test,
b) Expected variability of use conditions for the equipment,
c) Likelihood of different stress factors represented in the use conditions to be failure-promoting,
d) Relative costs of tests with alternative test conditions,
e) Test facilities available,
f) Test time available, and
g) Predicted values of the reliability characteristics as a function of test conditions.

10.1.2 If the reason for testing is to show that the equipment reliability is not below a certain level that might be critical from, say, a safety point of view, the test conditions shall not exclude any important extreme severities of use conditions. If the level of reliability applicable to the normal use conditions is to be demonstrated or determined, such as for optimization of maintenance planning, the test conditions should be highly realistic and representative of typical use conditions. If the reason is to compare different versions of an equipment with reasonably discriminative test results , reproducible test conditions are essential with stress levels approaching the limiting use conditions. In any case, the severities of the different stress factors should not exceed the limiting stress values which the equipment is specified to withstand.

10.1.3 Where several operating, environmental and maintenance conditions shall be taken into account during the test, these varying conditions are to be satisfied by the choice of an appropriate test cycle. The detailed reliability test specification should include a diagram showing the occurrences, durations, time intervals and interrelationships of the operating, environmental and preventive maintenance conditions in the test cycle.

10.1.4 The duration of the test cycle shall be short enough not to substantially influence the test results. The test cycle shall, however, be long enough to permit stabilization of the required test conditions. In case of a constant failure rate, the test cycle shall be less than 0.2 m_0 measured in accumulated relevant test time, where m_0 is the specified acceptable mean time between failures or the mean time between failures corresponding to the acceptable value of the reliability characteristic specified (*see also* **11.1.3**).

10.1.5 Whenever possible, the test conditions should be chosen among those given in IS 8161 (Part 3). For applications not covered in IS 8161(Part 3) an appropriate test cycle should be used according to IS 8161(Part 2).

10.2 Operating and Environmental Test Conditions

10.2.1 The operating and environmental test conditions shall, whenever possible, cover the range of operating and environmental conditions prevailing during actual field use.

10.2.2 In general, acceleration of the test by increasing the stress levels with respect to field use should not be applied. Acceleration of the operating test conditions in the sense of calender time compression may be considered for equipment, where the reliability characteristics are dependent mainly on the number of operating cycles.

10.2.3 The following categories of operating conditions shall be described in the detailed reliability test specification as far as they are applicable.

a) *Functional modes* — Complex equipment may have several defined and different functional modes. The operational profile for the equipment during actual field use defines the percentage of time spent in each mode, and also the pattern of transition from one mode to another. The transitions may be executed by direct operator control or automatically by programming signals.

   For example, a consumer radio set could be operated as a VHF receiver or as a phono-amplifier; a measuring equipment could be operated as a digital voltmeter or as a counter; a radar system could be operated by manual or automatic tracking.

b) *Input signals* — The requirements on the input signal characteristics shall be specified with acceptable tolerances on all measurable signal parameters which may influence the operation of the equipment in the test. This is particularly important in the case of complex test equipment interface, to make it possible to distinguish between failure of the equipment under test and failure of the test equipment.

c) *Load conditions* — The load conditions, electrical and mechanical, generally form a considerable part of the stresses imposed upon the test items and shall, therefore, be carefully specified. Electrical leads may be characterized by their input impedance and any transient behaviour. Mechanical loads may be of either static or dynamic character. The actual power output of the item as a part of the load conditions shall be specified and used in the testing.

d) *Actual manipulation of the equipment* — Actual handling of operator controls is often necessary to simulate field use. Excessive and

uncontrolled handling might on the other hand impose unintended stresses on the equipment. The requirements and the restrictions shall be stated in the detailed reliability test specifications.

e) *Supporting supplies* — Required characteristics, for example, voltage, frequency, waveform, transients, etc, of external electrical power supplies shall be specified with tolerances. The requirements on other supplies such as water and pressurized air shall be stated when applicable.

For equipment using artificial cooling from an external supply, the actual temperature stresses are completely or partly determined by the cooling system characteristics. The requirements of cooling system parameters, flow rate, inlet temperature, humidity, cleanliness, etc, shall be stated in the detailed reliability test specification.

10.2.4 The environmental conditions during field use usually consist of combinations and sequences of many environmental factors of varying severities. The practice simulation of the use environment during testing is, however, normally not economically possible and may also not be important from a testing point of view.

10.2.5 For laboratory testing the environmental factors may be applied singly, in combination or in sequence. The environmental test procedures should, whenever possible, be based upon the tests specified in IS 2106 (Parts 1 to 18). The detailed reliability test specification shall state the environmental test conditions to be used, preferably by specifying the sequence of and transitions between the standardized tests, and giving the 'Information required in the relevant specification' as listed in the appropriate part of IS 2106. Complete information on tests not included in or deviating from IS 2106 shall be given.

NOTE — IS 2106 covers environmental tests for electronic and electrical equipment in different parts.

10.2.6 Detailed guidance for selection of operating and environmental test conditions are given in IS 8161 (Part 2).

10.3 Preventive Maintenance During the Test

10.3.1 A preventive maintenance programme may be considered for the reliability test for those types of equipments where the equipment specification requires maintenance actions to be carried out as a normal routine during actual use. In any case, the preventive maintenance actions during test shall not differ in principle from those applied in actual field use, and the amount of test preventive maintenance shall not exceed the actual use preventive maintenance.

10.3.2 Typical categories of preventive maintenance actions are: replacement, adjustment, alignment, lubrication, cleaning, resetting, restoring, etc.

10.3.3 The programme shall at least define:

a) The preventive maintenance actions to be taken, and

b) The preventive maintenance intervals or times or other criteria governing the need for preventive maintenance.

10.3.4 The programme may include the functional check-out and necessary replacement of redundant elements to the extent that this is a specified procedure in field use. The preventive maintenance intervals or times or other criteria shall be stated before the beginning of the test in the detailed reliability test specification. The intervals or times may be specified in terms of operating time or calender time or relevant test time (number of cycles). They shall be specified in proper phase relationship to other cycled events or activities of the reliability test.

10.4 Preferred Laboratory Test Conditions

The operating environmental and maintenance use conditions show a great variety of combinations, sequences and severities in most applications. Some groups of applications are, however, similar and frequency enough to motivate standardized test cycles to be preferred for laboratory compliance and determination testing. These preferred test conditions are specified in detail in IS 8161 (Part 3) and should be used whenever possible.

11 TEST ITEM PERFORMANCE AND TEST OBSERVATIONS

Depending on the type of reliability testing being performed, the relevant test time to relevant test item failures shall be observed during the test or the number of relevant failures observed at the termination of the test. The monitoring of test item performance and the defintions of failures and relevant test time therefore be clearly stated in the detailed reliability test specification. The clauses below give rules and guidance on this matter.

11.1 Monitoring of Test Item Performance

The following aspects on monitoring of test item performances shall be clarified in the detailed reliability test specifications.

11.1.1 *Parameters*

The functional test item parameters to be monitored during the test shall be specified. Monitoring all or only some of the parameters specified in the equpment specification may be required. Mainly output parameters should be considered. In case of

redundancy within the equipment to be tested, monitoring of parameters of redundant units should be considered.

11.1.2 *Measuring*

The measuring method and the measuring accuracy required shall be specified for each monitored parameter. Procedures for estimating the total measuring error shall be given, if applicable.

11.1.3 *Monitoring Interval*

Monitoring should be continuous at intervals. If monitoring cannot be made continuously, the time interval between monitoring and the points in the test cycle at which monitoring shall be done shall be specified.

The time interval between monitoring shall be short enough not to substantially influence the test result. In case of a constant failure rate, the interval of accumulated relevant test time shall be less than $0.2\ m_0$, where m_0 is the specified acceptable mean time between failure or the mean time between failure corresponding to the acceptable value of the reliability characteristic specified.

NOTE — The value $0.2\ m_0$ is based on an investigation to limit the effect of the length of the monitoring interval on the producer's and consumer's risks.

11.2 Test Item Failures

11.2.1 For each parameter to be monitored, the limits for acceptable performance shall be specified. A failure shall be considered to have occurred when any of these limits are exceeded permanently or intermittently. All failures shall be analyzed in accordance with **12.3**.

11.2.2 Failure indications caused by erroneous measurements of failures in external measuring equipment are not considered test item failures. All other failures shall be considered test item failures.

11.2.3 If more than one parameter has gone beyond its specified limits, each of these deviations shall be considered one test item failure, if it has not been proved that they are due to the same failure cause, in which case they are combined and considered as one test item failure.

11.2.4 If two or more independent failure causes are present, each of these shall be considered as one test item failure.

11.2.5 Each test item failure shall be classified as a relevant or a non-relevant failure. All test item failures that cannot be clearly classified as non-relevant failures according to **11.3** or to any additional rules given in the detailed reliability test specification shall be considered relevant test item failures.

11.2.6 All relevant test item failures observed during or at the termination of the test shall be taken into account for decision making in reliability compliance tests and for determining point estimates and confidence limits in reliability determination tests.

11.3 Classes of Non-relevant Failures

A test item failure may be regarded as a non-relevant failure only if the circumstances at the occurrence show clear evidence to classify it into one of the classes defined in **11.3.1** to **11.3.3**. The evidence shall be documented and included in the test report. Additional classes of non-relevant failures applicable in a particular case may be defined in the detailed reliability test specification.

11.3.1 *Secondary Failures*

A secondary failure is defined as a failure of an item caused either directly or indirectly by the failure of another item.

Secondary failures are considered non-relevant with exception given in the note. The corresponding primary failure is always a relevant failure if it is located in the test item. It may be noted that a secondary failure may occur after a time delay from the occurrence of the primary failure. The duration of the time delay shall be approved by the customer or test agency.

NOTE — A secondary failure may also be classified as failures demanding immediate reject decision (*see* **11.4.1**).

11.3.2 *Misuse Failures*

A misuse failure is defined as a failure attributable to the application of stresses beyond the stated capabilities of the item.

Misuse failures during testing may be due to unintentional test conditions, for example, test severities exceeding those specified for the equipment under test, rough handling by test or repair personnal, etc. Misuse failures are always considered non-relevant.

NOTE — A misuse failure may also be classified as failures demanding immediate reject decision (*see* **11.4.1**).

11.3.3 *Corrected-Design Failures*

During the time span of the reliability testing, a type of failure observed early in the test may result in a design change or other remedy implemented on all equipments in the population. If such a corrective action is proved to be effective, the failures of this type may be reclassified as non-relevant failures upon agreement.

11.4 Special Classes of Relevant Failures

Failures demanding immediate reject decision and recurrent failures are the only classes defined below.

The detailed reliability test specification may define additional special classes of test item failures based, for example, on the effect upon system performance, on the location of the failure with respect to redundant units or non-essential units in the equipment or on repair costs and time. The types of failures defined in IS 1885 (Part 39) may be useful for this purpose.

11.4.1 *Failures Demanding Immediate Reject Decision*

In particular cases for reliability compliance tests, it may be appropriate to define those test item failures whose occurrence, regardless of the number, shall result in an immediate reject decision which overrides the normal accept/reject criteria. In these cases, the definition of such failures shall be included in the detailed reliability test specification.

For example, test item failures which are likely to result in hazardous or unsafe conditions for persons using, maintaining or depending on the equipment, or failures which are likely to cause great material damage should be considered in this category.

11.4.2 *Recurrent Failures*

Occurence of recurrent failures may imply weakness in the equipment design or indicate the use of components of inferior quality. Recurrent failures are an important indication of possible wear or other degradation which result in increasing failure rate.

When recurrent failures occur, special investigations should be instituted in order to reveal the cause of recurrence and their possible effects on distribution assumption [*See* IS 8161 (Part 6)].

11.5 Relevant Test Time

11.5.1 Relevant test time is the time used in connection with the number of relevant test item failures to show compliance with reliability requirements or to calculate the value of a reliability characteristic.

11.5.2 The relevant test time to be recorded during the testing may be the individual relevant time for each test item or the accumulated relevant times added from all test items as specified by the detailed reliability test specification. Any burn-in time, maintenance time and down time of the test items shall be excluded. In case of monitoring at intervals, a failure shall be considered to have occurred immediately before it was observed.

NOTE — This convention of assigning accumulated relevant time for the failure up to the observations is chosen to limit the effects on producer's and consumer's risks with a small number of test items.

11.5.3 The detailed reliability test specification may prescribe a minimum and/or a maximum relevant test time on each individual test item.

11.5.4 For test items consisting of two or more separate sub-units (for example, pieces of equipment), the relevant test time recorded for the test item shall be the minimum relevant test time on any of its sub-units.

12 GENERAL TEST PROCEDURE

12.1 Test Operations

12.1.1 No actions are allowed on the test items from the time of sampling until the test starts, if not otherwise specified in the detailed reliability test specification. The original units, components, etc, in the test items should be kept unchanged during the test period except for allowed maintenance and modifications as noted in **11.3.3**.

12.1.2 If an interruption is made in the test for preventive or corrective maintenance or for administrative reasons or for any other (unforeseen) reason, the test shall be resumed with a minimum of delay and, in case of cycled test conditions, at a point in the cycle corresponding to the point of interruption, if not otherwise specified.

12.1.3 If applicable, the detailed reliability test specification shall state the conceivable interruptions allowed in the test, the maximum duration or such interruptions and the time phases of allowed resumption in case of cycled test conditions.

12.2 Corrective Maintenance

12.2.1 The detailed reliability test specification shall indicate the replacement policy to be used for repairable equipment, that is, the level (sub-units, sub-assemblies, parts, etc) at which repairs or replacement are allowed during the test.

12.2.2 The following actions shall be taken when a test item failure is observed:

a) The test item failure shall be adequately recorded and confirmed as far as possible. If it is not possible to confirm the failure symptom subsequent steps indicated may only be partly applicable.

b) The failure location shall be determined and necessary failure analysis and diagnostic tests be started in order to find the failure cause.

c) A first assessment shall be made to determine the class in which the failure shall be classified. The final classification should be deferred until the report from the failure analysis of units, components, etc, is available.

d) An assessment shall be made to trace possible secondary failures.

e) Based on steps (a) to (d), a decision shall be made on the extent of necessary repair, if any.

f) The repair shall be performed. Failed non-repairable units, components, etc, shall be carefully stored in their actual condition for detailed failure analysis.

g) If the type of test so permits, the repaired test item shall be put back in test without delay.

12.2.3 Following the corrective maintenance and prior to the resumption of the test, it is permissible to test the performance of the test item in the test facility. The detailed reliability test specification should specify, for all replaceable units or components of the equipment under test, the period of operation (or number of cycles), which should be used to verify the effectiveness of the repair. Failures and time during this period should be recorded and reported but not considered as relevant test time unless otherwise specified in the detailed reliability test specification.

12.2.4 In the case of a wrong diagnosis and if the replacement of a unit or a component does not eliminate the failure, the original item should be reinstalled, if possible, and the fault finding procedure should continue.

12.3 Failure Analysis and Classification

The cause of each test item failure shall be determined by investigation and analysis. Sufficient investigation shall be carried out so as to permit the failure to be classified with maximum certainty, consistent with available evidence, as a relevant or non-relevant failure. Further investigation of failure causes might be required for corrective maintenance and corrective action.

12.4 Recording of Test Conditions and Observations

12.4.1 The test records together with the final failure analysis reports shall contain all primary information needed to make a complete data analysis as a basis to reach a decision from the outcome of the test. Test records shall be maintained throughout the testing. Continuous recording of test conditions and test item performance is preferred.

12.4.2 Any event considered pertinent to the test by the test personnel should be noted in the records. The data to be recorded and the extent of the recordings shall be stated in the detailed reliability test specification. Test records shall preferably be designed in a form that allows the test personnel to make all entries directly.

12.4.3 For each test item, records should be maintained as follows:

a) Data and time as well as elapsed relevant test time when any test item failure or any other pertinent event was observed or an action was taken.

b) Details of any failure analysis and all information of importance for the classification of the failures observed, including reference to the failure reports.

c) Description of any event or action, including defined preventive maintenance tasks listed in the detailed reliability specification.

d) Identification of replaced or reinstalled units, components, etc.

e) Operating and environmental test condition data.

f) Time for the verification of the effectiveness of any corrective maintenance.

g) Names of the test personnel and operators of the test items.

12.5 Interpretation of Test Results

The test data records shall be interpreted to prepare for final decisions and conclusions. The interpretation should propose final acceptance or corrective actions resulting from the reliability compliance test or include reliability characteristics resulting from a reliability determination test.

12.5.1 *Final Classification of Failures*

12.5.1.1 The data from each failure shall be examined successively during the testing and final classification into relevant or non-relevant test item failures shall be made as soon as complete data are available (*see* **11.2**).

12.5.1.2 Any failure demanding immediate reject decision or any recurrent failures shall be particularly noted (*see* **11.3**).

12.5.1.3 Additional classification of failures may be required in the detailed reliability test specification.

12.5.2 *Statistical Treatment*

12.5.2.1 The data on relevant test times to and between failures and the number of relevant failures shall be treated statistically in accordance with the relevant parts on tests for the validity of assumptions, test plans for compliance tests and procedures for making estimates from determination test [*see* **9** and IS 8161 (Parts 4 to 7)].

12.5.2.2 The statistical treatment shall result in an accept or reject decision based on the criteria of the test plan or in estimates of the reliability characteristic required.

12.5.3 *Final Conclusions and Possible Actions to be Taken*

This clause is mainly applicable to reliability compliance test.

12.5.3.1 *Acceptance*

If no failures demanding immediate reject decision or no recurrent failures have occurred (*see* **11.4**) and the statistical treatment results in an acceptance decision, the equipment tested shall be accepted without any further action.

12.5.3.2 *Conditional acceptance*

If acceptance according to **12.5.3.1** is not possible, the equipment may, upon agreement, be accepted under certain conditions. These conditions may be:

a) improvement of the equipment design or manufacture;
b) improvement of the specified preventive maintenance;
c) improvement of operator instructions;
d) change of the detailed reliability test specification (for example, increasing the decision risks); and
e) change of the equipment specification.

12.5.3.3 *Rejection*

If neither acceptance according to **12.5.3.1** nor conditional aceptance according to **12.5.3.2** is possible, the equipment shall be rejected.

13 FIELD TESTING CONSIDERATIONS

During a field reliability test, the test items are in operational use and special considerations shall be taken into account in defining and interpreting test conditions, test item performance and relevant test time, and in recording observations by data collection.

13.1 Test Conditions

13.1.1 For field reliability testing, the operating and environmental conditions need not be simulated. On the other hand, more operating and environmental test factors will usually be present than in the case of laboratory testing. Limits of the severities of all the operating and environmental factors shall be specified in the detailed reliability test specification. Special attention shall be paid not to overlook factors which may have an impact on the equipment reliability.

13.1.2 If there are several sites available for the field reliability testing, the choice of test site(s) depends on the basic reasons for the testing:

a) If a high assurance is required that the achieved reliability level is not below a specified value, sites with the most severe conditions shall be chosen.
b) For determination of the level of reliability applicable to normal use conditions or for optimization of maintenance planning, sites with the most typical conditions shall be chosen.
c) If comparative reliability information is requested, the sites shall have the same or nominally identical conditions.

13.1.3 The operating and environmental test conditions shall preferably be monitored continuously during the test period. If this is not possible during the normal field use of the equipment, monitoring shall be done on a time sampling basis and/or the reported observations of the operators shall be used.

13.1.4 The normal prescribed maintenance programme shall be carried out strictly and by qualified personnel. It is important to note the training experience and the main traits of character of the operators and maintenance personnel, together with the circumstances under which any actions were performed.

13.1.5 If possible, the testing shall be interrupted when the test conditions go outside the specified limits. If it is found that the test conditions have been outside the specified limits during testing, an analysis should be made to investigate whether this might have influenced the equipment reliability. If so, the failures and test time during the period in which the specified limits have been exceeded shall be considered non-relevant and be recorded but not counted in the test results. In extreme cases it might be necessary to invalidate the complete field test programme.

13.2 Test Item Performance and Relevant Test Time

13.2.1 The time intervals and procedure of monitoring of the test item performance shall be stated in the detailed reliability test specification (*see* **11.1**).

13.2.2 All disturbances shall be reported, including those which could not be verified. It may be useful to consider whether certain factors could contribute to an over or under critical attitude of the operators.

13.2.3 The relevant test time shall be defined in the detailed reliability test specification. If equipment operating time is taken as a basis, an elapsed time indicator or cycle counter installed in every equipment on test is recommended. Clock readings shall be recorded at each failure observation and maintenance action. Where impractical, another time basis, such as vehicle usage time (for example, flight time for airborne equipment), may be used with or without the application of an appropriate correction factor.

13.3 Data Collection

13.3.1 In order to obtain accurate and complete field feedback information within a reasonable time, it is recommended that:

a) a special reporting routing be organized which links the field engineers with the reliability and product engineers,
b) the responsible field engineers be accustomed to a uniform field test procedure, and
c) the number of recording and reporting forms be a minimum.

13.3.2 The collection of data should be in accordance with IS 7354 (Part 4).

13.3.3 If the number of the equipments on test is small, data gathering may be possible by the normal field maintenance personnel using the existing maintenance forms. If the equipment is complex and/or the number of test items is large, it is recommended that specially trained personnel collect the data and that special field report forms be used.

13.3.4 The data to be collected shall include installation details, where these might affect the equipment reliability. The reports shall also describe in detail the operating and environmental conditions during the test period.

13.3.5 Since the test results are derived from field reports, an analysis is needed to assure the trustworthiness and completeness of these reports. Decisions have to be made as to which of the reported failures shall be regarded as relevant (*see* **11**).

13.3.6 The application of automotic data processing has to be considered if the amount of field data is large. Automatic data processing requires encoding of the field information. This can be done in the field or at the plant. Field encoding results in shorter reports and faster processing of the information. In-plant encoding has the advantage that a relatively small number of trained personnel may provide consistently encoded information with minimum errors, while the field engineers are able to express their findings more accurately.

14 TEST REPORTS

The test report shall be complete enough to give a solid basis for the final decision or determination. It should contain the documents referred to in **14.1** to **14.5**. Each of the documents required should refer to the equipment under test and the detailed reliability test specification.

The test report should call attention to the history of the particular piece of equipment together with the special notations on the stresses which may have been involved in the past and contributed to a possible failure mechanism. Success as well as failure information should be accumulated if the full picture is to be available to the reliability engineers.

14.1 Test Logs and Data Records

14.1.1 One document should be established for each test item. Chronological data are recorded at defined times and after each failure (*see* **12.4**). The contents of test logs and data records shall be as follows:

a) Equipment identification:
   1) Equipment name,
   2) Name of manufacturer,
   3) Equipment type, and
   4) Serial numbers of the test items.
b) Chronological recording for each observation and action:
   1) Data and time,
   2) Operating conditions,
   3) Environmental conditions,
   4) Performance parameters values,
   5) Comments on out-of-specification conditions,
   6) Time meter reading, and
   7) Names of personnel involved.
c) General comments.

14.2 Failure Reports

One report should be made on each failure containing the description of the failure, the result of the failure analysis and the actions taken concerning the equipment and the components or parts.

Originators and detailed contents should be as listed in **14.2.1** to **14.2.3**.

14.2.1 *From the Test Operator*

a) 1) Date and calendar time of the failure,
   2) Serial and calendar time of the failure,
   3) Assembly, sub-assembly, component or part involved,
   4) Operating conditions at the instant of failure,
   5) Environmental conditions at the instant of failure,
   6) Time meter reading, and
   7) Name of test operator.
b) Failure symptom:
   1) Nature of any partial or complete failure,
   2) Values of parameters exceeding specified limits, and
   3) Instruments used for indicating the failure.
c) Reference to related failure reports;

d) Opinion concerning the classification of the failure;

e) Recommended corrective action; and

f) General comments.

14.2.2 *From the Repairing Personnel*

a) Failure confirmation:
   1) Method and instruments used, and
   2) Observations and comments.

b) Repair description:
   1) Actions taken,
   2) On-time of the equipment during the repair,
   3) Date, time and duration of repair, and
   4) Organization and name of repair personnel.

c) Replacement identification for each component or part replaced:
   1) Location or circuit position,
   2) Name of the component or part,
   3) Type designation and characteristics, and
   4) Name of manufacturer.

d) Opinion concerning the cause and classification of the failure;

e) Recommended corrective action or authorized modification introduced to remedy the failure; and

f) General comments.

14.2.3 *From the Failure Analysis Personnel*

a) Analysis of the replaced components or parts:
   1) Visual examination and initial measurements;
   2) Analysis description (physical, chemical, etc);
   3) Result;
   4) Date of analysis; and
   5) Organization and name of analysis personnel;

b) Analysis of conditions influencing the failure;

c) Cause and classification of the failure;

d) Recommended corrective action; and

e) General comments.

14.3 Failure Summary Record

This single document should contain summarized information on all failures. Failure data and relevant test time should be traceable to the originating test log and failure reports. The contents of the failure summary record shall be as follows:

a) General information:
   1) Equipment identification, and
   2) Reference to the detailed reliability test specification;

b) Chronological summary of all the relevant failures;
   1) Failure data and time,
   2) Failure classification,
   3) Reference to failure report,
   4) Test item serial number,
   5) Accumulated number of relevant failures, and
   6) Accumulated relevant test time;

c) Summary of all the non-relevant failures;
   1) Failure classification, and
   2) Reference to failure report; and

d) Down time and repair time information.

14.4 Failed Replacement Units and Spare Parts Inventory (Optional)

This inventory should give information about the failure rate and frequency of replacement units and spare parts and is intended for maintenance planning and logistic support. The contents of the failed replacement units and spare parts inventory shall be as under:

a) General information:
   1) Equipment identification, and
   2) Reference to the detailed reliability test specification; and

b) Inventory for each replacement unit and spare part:
   1) Identification,
   2) Conditions of use during the test,
   3) Total number in the equipment,
   4) Total number failed, and
   5) Total accumulated relevant test time.

14.5 Final Report

The final report resulting from the reliability compliance or determination testing should contain:

a) Failure summary record (*see* **14.5**);

b) Plots and values presenting the result of the statistical treatment; and

c) Final conclusions and proposed actions to be taken, if applicable.

15 SUMMARY OF DETAILES TO BE INCLUDED IN THE DETAILED RELIABILITY TEST SPECIFICATION OR THE EQUIPMENT SPECIFICATION

15.1 When reliability compliance or determination

tests shall be performed according to this standard, the following items shall be given in the detailed reliability test specification or the equipment specification or elsewhere in the set of documents relevant to the equipment in question, as far as they are applicable. All items with no explicit reference to compliance or determination testing are valid for both. The same applies for laboratory and field testing:

		Clause Ref
1)	List of requirements for compliance testing	**7.2**
2)	General contents of the detailed reliability test specification	**7.3**
3)	Applicable reliability characteristics for determination testing	**8**
4)	Requirements for determination testing	**8**
5)	Relevant equipment population	**9.2**
6)	Any special procedure of test item selection	**9.2**
7)	Assumed distribution, if other than exponential	**9.3.2**
8)	Requirement to perform validity test	**9.3.2**
9)	Test plan for compliance testing	**9.4**
10)	Specification of test cycle	**10.1**
11)	Operating conditions	**10.2**
12)	Environmental conditions	**10.2**
13)	Preventive maintenance	**10.3**
14)	Any preferred conditions to be used	**10.4**
15)	Test item parameters to be monitored	**11.1.1**
16)	Parameter measuring	**11.1.2**
17)	Monitoring interval	**11.1.3**
18)	Limits for acceptable performance	**11.2**
19)	Any additional classes of non-relevant failures	**11.3**
20)	Any additional special classes of failures	**11.4**
21)	Definition of failures demanding immediate reject decision	**11.4.1**
22)	Relevant test time	**11.5**
23)	Minimum and/or maximum test time on each test item	**11.5**
24)	Any actions on test items before test starts	**12.1**
25)	Test interruptions allowed	**12.1**
26)	Allowed time phases for resuming test	**12.1**
27)	Replacement policy	**12.2**
28)	Operation to verify effectiveness of repair	**12.2**
29)	Data to be recorded, extent of recordings	**12.4**
30)	Limits of conditions for field testing	**13.1**
31)	Monitoring of test items for field testing	**13.2**
32)	Relevant test time for field testing	**13.2**

ANNEX A

(Foreword)

FLOW CHART DESCRIBING PREPARATIONS FOR AND EXECUTION OF RELIABILITY TESTS

A-1 OBJECT

A-1.1 This annex is intended to give brief diagrammatic guidance to the test specification writer and the test engineer on how to use IS 8161 series preparing for executing, and interpreting equipment reliability tests.

A-2 CONTENTS

A-2.1 Chart 1 gives a sequence of steps for preparing the detailed reliability test specification necessary before starting an equipment reliability test.

A-2.2 Chart 2 gives a sequence of steps for executing and interpreting the test.

A-2.3 At each step, reference is made to applicable clauses of IS 8161 (Part 1) and to other relevant parts of this standard.

CHART 1

(Clause A-2.1)

SEQUENCES FOR PREPRATION OF THE DETAILED RELIABILITY TEST SPECIFICATION

Consider basic principles,	*Aspects concerning* — *Statistics:*
3, 4, 5 and **6** of this standard	In general: **9** of this standard
	Determination tests: IS 8161(Part 4): Procedures for determining point estimates and confidence limits from equipment reliability determination tests.
Consider requirements for compliance tests: **7.1** and **7.2** of this standard for determination tests.	Compliance tests: IS 8161 (Part 5) : Compliance test plans for success ratio, and (Part 7) : Compliance test plans for failure rate and mean time between failures assuming constant failure rate.
8 of this standard	Validity tests: Constant failure rate IS 8161 (Part 6/Sec 1 and 2): Tests for the validity of a constant failure rate assumption
Consider test methods: **7.3** or **8** of this standard	— *Test conditions*: **10** and **13.1** of this standard Preferred conditions: (Part 3): Preferred test conditions. Tailor-made test cycles: (Part 2): Guidance for the design of test cycles. — *Performance and failure*: **11** of this standard
Consider test execution **12** of this standard	*Aspects concerning*: —Field tests:
Review and complete test specification **15** of this standard	**13** of this standard —*Reporting*
Detailed reliability test specification	**14** of this standard

CHART 2

(*Clause* A-2.2)

SEQUENCE OF ACTIVITIES FOR EXECUTION AND INTERPRETATION OF THE TEST

Detailed reliability test specification

Test set-up and preparations

Start (or restart) test execution and relevant test
12.1 of this standard

Corrective maintenance:
12.2 of this standard

Test observations and test data recordings:
12.4 and **13.2** of this standard

Failure analysis:
13.3 of this standard

Final failure classification:
12.5.1 of this standard

Statistical treatment:
13.5.2 of this standard

Final conclusions:
12.5.3 of this standard

Final Report:
14.5 of this standard

Aspects concerning:

— *Determination tests*:

IS 8161 (Part 4): Procedures for determining point estimates and confidence limits from equipment reliability determination tests.

— *Compliance tests*:

IS 8161(Part 5): Compliance test plans for success ratio.

IS 8161 (Part 7): Compliance test plans for failure rate and mean time between failures assuming constant failure rate.

— *Validity tests*:

IS 8161(Part 6/Sec 1 and 2): Tests for the validity of a constant failure rate assumption.

ANNEX B

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
1885 (Part 39) : 1999	Electrotechnical vocabulary: Part 39 Dependability of electronic and electrical items (*second revision*)
2106 (Parts 1 to 18)	Environmental tests for electronic and electrical equipment
7354	Guide on reliability of electronic and electrical items:
(Part 1) : 1975	Preliminary reliability considerations
(Part 2) : 1984	Reliability and maintanability management (*First Revision*)
(Part 4) : 1974	Collection of reliability availability and maintanibility data from field performance
8161: 1986	Guide for equipment reliability testing:
(Part 2) : 1986	Guidance for the design of test cycles for equipment reliability testing
(Part 3) : 1986	Preferred test conditions for equipment reliability testing
(Part 4) : 1985	Procedures for determining point estimates and confidence limits from equipment reliability determination tests
(Part 5) : 1981	Compliance test plans for success ratio
(Part 6/Sec 1) : 1983	Tests for the validity of a constant failure rate assumption, Section 1 Chi-square test
(Part 6/Sec 2) : 1987	Tests for the validity of a constant failure rate assumption, Section 2 Kolmogorov-smirnov test
(Part 7) : 1977	Compliance test plans for failure rate and mean time between failures assuming constant failure rate
(Part 11) : 1983	Flow chart describing preparations for and execution of reliability tests

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Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards: Monthly Additions'.

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